North Dakota Water Resources Research Institute
Annual Technical Report
FY 2014

Introduction

This report describes the activities of the North Dakota Water Resources Research Institute (NDWRRI) during the period of March 1, 2014 to February 28, 2015.

The ND WRRI is one of the 54 institutes known collectively as the National Institutes for Water Resources (NIWR). The NDWRRI was founded in 1965, by authority of Congress (Water Resources Research Acts of 1964, 1972, 1984, and 1990), and is administrated through the United States Geological Survey. Section 104 of the Water Resources Research Act requires the NDWRRI to apply its Federal allotment funds to:

1. Plan, conduct or otherwise arrange for competent research that fosters: (A) the entry of new research scientists into the water resources field, (B) training and education of future water resources scientists, engineers, and technicians; (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and (D) the dissemination of research results to water managers and public.

2. Cooperate closely with other college and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems

3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

This year, NDWRRI once again allocated its 104(B) resources to fund Graduate Fellowship research projects. The institute also continued its efforts to enhance communication between the State and Federal agency personnel and university faculty and students. NDWRRI also worked closely with the Environmental and Conservation Sciences program of North Dakota State University (NDSU), Natural Resources Management program of NDSU, and the International Water Institute, Fargo, ND on water related research issues and collaboration.

The annual base grant amount received by the WRRI was $92,335. The amount was used for administration and Fellowship awards. The Fellowship program was supported by the North Dakota State Water Commission with an additional amount of $13,850.

Program Management

The Institute continued the same administrative mechanism with a director managing the institute program with the help of a State Advisory Committee. Dr. G. Padmanabhan, Professor of Civil Engineering, continued as the director. Linda Charlton, a NDSU employee, has been working part-time for the Institute to assist the director with Institute finances, communications and information transfer. The State Advisory Committee consists of three members representing the three principal water agencies in North Dakota: State Water Commission, State Department of Health, and the USGS North Dakota District. In addition, the Institute also seeks advice from the faculty of the two research universities of the State: North Dakota State University and University of North Dakota.

Dr. G. Padmanabhan stepped down from the directorship at the end of the funding cycle effective February 28, 2015. Dr. Eakalak Khan, Professor of Civil and Environmental Engineering and the Director of NDSU Environmental and Conservation Sciences Graduate Program, assumed charges as the director from March 1, 2015.

State Appropriation

The State Water Commission continued its support of 15% match ($13,850) to the 2014-2015 Graduate Research Fellowship program of NDWRRI under federal 104 (B) funding. This is eleventh year the SWC provided support to the Fellowship program.

University Support

North Dakota State University and the University of North Dakota administrations consider the NDWRRI activities important and are supportive of its efforts.

Institute Location

The Institute continues to operate from the Administrative Building of the College of Engineering and Architecture of North Dakota State University in Fargo, North Dakota. The director may be reached at: ND Water Resources Research Institute, North Dakota State University, Civil and Environmental Engineering, Dept. # 2470, Fargo, ND 58108-6050 Phone: (701) 231-7717 Fax: (701) 231-6185 E-mail: Eakalak.Khan@ndsu.edu

State Advisory Committee

The State Advisory Committee provided guidance on water resources research priorities in the State and region, and participated in the review and evaluation of research proposals and projects. The current committee members are:

Gregg Wiche, District Chief, U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota

William Schuh, Water Appropriation Division, North Dakota State Water Commission, Bismarck North Dakota

Peter Wax, Water quality Special Projects, ND Department of Health, Bismarck, North Dakota

The committee members are senior officials in the three major agencies in North Dakota responsible for much of the water resources research done outside of NDSU and UND in North Dakota.

Research Program Introduction

ANNUAL BASE GRANT (104-B)

In the past several years NDWRRI has offered competitive fellowships to NDSU and UND graduate students for research on water resources topics under a Graduate Research Fellowship (GRF) program effectively using the modest amount of the 104(B) annual base grant. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984.

The fellowship program encourages entry of young university faculty and new research scientists into the water resources field;

provides training and education to future water resource scientists and engineers;

promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and

engages university faculty in collaborative research programs seeking supports from entities concerned with water problems.

This year also, the NDWRRI continued the GRF program and applied bulk of the federal allotment to it. The GRF program is administrated and monitored by the director. Applications are invited from the graduate students and their advisors of the two research universities of the State, NDSU and UND. A rigorous review by the State Advisory Committee and other water professionals in the state determines the awards. Active participation of the academic advisors of the students in meeting matching requirement and seeking co-funding from local, state and other sources is another positive aspect of the program. Periodical review of the progress of the students in meeting the fellowship expectations is ensured by seeking reports from the students and by encouraging them to make presentations in local, regional, and national technical seminars and conferences.

Guidelines for the 2014-2015 Graduate Research Fellowship were posted on the Institute website in September 2013, and the request for applications was announced in the faculty news publications of the two university campuses by the first week of November, 2013.

The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists. November 7, 2013 Issue of It's Happening at State (IHaS) (NDSU Publication) carried it. An announcement similar in content was also published in the University of North Dakota campus publication University Letter.

As it appeared in November 7, 2013 issue of IHaS:

ND Water Resources Research Institute seeks fellowship applicants

The North Dakota Water Resources Research Institute invites applications for its 2014 Graduate Research Fellowship program.

NDSU and University of North Dakota graduate students who are conducting or planning research in water resources may apply for fellowships of varying duration, ranging from three months to one year. Typically, fellowship awards range from $800 to $1,000 per month for master's degree students and $1,000 to $1,400 per month for doctoral students. The fellowship funds must be applied between March 1, 2014, and Feb. 28, 2015.

A technical completion report co-written by the fellow and the adviser is expected of each fellowship research project.

Research proposed for fellowship support should relate to water resources issues in the state or region. Regional, state or local collaborations or co-funding will strengthen an application. Fellowships have a matching requirement of two non-federal dollars to one federal dollar. At the time of applying, applicants should have a plan of study filed and/or should have a thesis research topic selected. Applications need to be prepared in consultation with advisers. The applications should be co-signed by the applicants advisers.

Applications from students and advisers who have not met the reporting requirements of their previous fellowship projects will not be considered for funding.

The general criteria used for proposal evaluation include scientific merit, originality, research related to state or region, and extent of regional, state or local collaboration and/or co-funding. A panel of state water resources professionals will review the proposals.

Award announcements will be made by early January, subject to the appropriation of funds for the fiscal year 2014 program by the federal government.

For more information about the program and guidelines for preparation of applications, visit www.ndsu.edu/wrri.

Applications are due Friday, Nov. 29, by 5 p.m.

Submit original and four hard copies of applications to Linda Charlton, Family Life Center (FLC 320), NDSU Department 2030, PO Box 6050, Fargo, ND 58108-6050 and an electronic copy in Word format to g.padmanabhan@ndsu.edu.

For additional information, contact G. Padmanabhan, professor of civil and environmental engineering, at g.padmanabhan@ndsu.edu or Linda Charlton, ITS tech coordinator, at linda.charlton@ndsu.edu.

NDWRRI GRADUATE RESEARCH FELLOWSHIPS

In total, seventeen applications were received. Twelve were from NDSU and five from UND. Out of seventeen, three (2 Ph. D and 1 MS) are for renewal and fourteen (6 Ph. D and 8 MS) are new applications. Approximately $70,000 was available for Fellowship projects from the annual base grant. An additional support of $13,850 came from ND SWC. Fellowships ranging from $1,000 to $10,000 were awarded to fifteen graduate students, 8 Ph.D. and 8 MS, conducting research in water resources topics at NDSU and UND. Selection of student Fellows and the award amounts were based on competitive proposals prepared by the students with the guidance of their advisers. A panel of state water resource professionals and the director reviewed the proposals and selected Fellows. The award amounts are based on the quality of proposals and the priority of the proposed projects for the state and region.

2014-15 ND WRRI Fellows, their advisers, and Fellowship research projects:

Dasuni Arachchige (Fellow), Geography, UND; Gregory Vandeberg (adviser) Flash Flood Potential Mapping Using GIS and Flash Flood Potential Index (FFPI) in Turtle River and Forest River Watersheds, North Dakota

Abbie Beaudry, Civil Engineering, UND; Howe Lim Nutrient Loading Reduction and Water Quality of Best Management Practices in Grand Forks, North Dakota

Derrick Deering, Civil Engineering, UND; Howe Lim Three Dimensional Analyses of Flow Dynamics & Chlorination of Ground Water Supply Reservoir in a Cold Region

Heather Dose, Soil Science, NDSU; Ann Marie Fortuna Where is fertilizer nitrogen going, up in smoke or down the pipe? An assessment of nitrogen transformations and water quality impacts on a tile drained sodic soil

Prosper Gbolo, Geology and Geologic Engineering, UND; Phillip Gerla The Cycling and Fate of Phosphorus at an Abandoned Feedlot

Noah Habtezion, Civil and Environmental Engineering, NDSU; Xuefeng Chu Quantification of Spatio-temporal Distribution of Surface Ponding and the Related Dynamic Processes

Yangbo He, Soil Science, NDSU; Thomas DeSutter Sodic soil characterization and management on subsurface drainage

Mohammad Hossain, Civil and Environmental Engineering, NDSU; Achintya Bezbaruah Biopolymers for Phosphate Removal from Eutrophic Lakes

Kelsey Kolars, Ag and Biosystems Engineering, NDSU; Xinhua Jia Development of a Model for Subsurface Drainage and Subirrigation Water Management

Navaratnam Leelaruban, Civil and Environmental Engineering, NDSU; G. Padmanabhan A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota

Debjit Roy, Ag and Biosystems Engineering, NDSU; Xinhua Jia Snowmelt water infiltration into frozen soil in Red River of the North Basin

Jingyi Sun, Ag and Biosystems Engineering, NDSU; Halis Simsek Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species

Mitchell Swanson, Civil and Environmental Engineering, NDSU; Eakalak Khan The Role of Algal Species on Phosphorus Bioavailability

Anthony Wamono, Ag and Biosystems Engineering, NDSU; Dean Steele Effects of calcium based surface amendments on the hydraulic conductivity and selected physical properties of subsurface drained sodic-saline soils

Lucas Wandrie, Biological Sciences, NDSU; Wendy Reed Bird-mediated transport of toxic heavy metals and selenium from marine and terrestrial sources to freshwater wetlands in North Dakota.

Nutrient Loading Reduction and Water Quality of Best Management Practices in Grand Forks, North Dakota

Basic Information

Title:	Nutrient Loading Reduction and Water Quality of Best Management Practices in Grand Forks, North Dakota
Project Number:	2014ND282B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Nutrients, Surface Water, Non Point Pollution
Descriptors:	None
Principal Investigators:	Yeo Howe Lim

Publications

1. Abbie, B. and Lim, Y.H. (2014). Performance of Pervious Concrete on Runoff Reduction in Grand Forks, ND. Proc., World Environmental and Water Resources Congress 2014- Water Without Borders, p 135-144, Environmental and Water Resources Institute, ASCE, Portland, Oregon, June 2014
2. Beaudry, Abbie., May 2014, Removal Efficiency of Water Quality Pollutants in a Wet Detention Basin in Grand Forks, ND., MS in Civil Engineering, College of Engineering & Mines, University of North Dakota, Grand Forks, North Dakota.

Research:

When an urban area develops over time, an increase in impervious land surface occurs, which impacts the stormwater runoff within the drainage basin. Developers and engineers are many times required to have post-development stormwater impacts to be the same, if not better, than prior to development. This is accomplished by installation of structures such as retention ponds, detention ponds, infiltration beds, etc. that are commonly known as Best Management Practices (BMP's).

Grand Forks, ND has many in-situ BMP's located throughout the city. Until now, these structures have been assumed to be functioning the way they were intended to when designed: to increase water quality and decrease runoff quantity. In reality, however, there is currently no comprehensive data collection scheme in place to accurately assess the effectiveness of the BMP's in general, and the structures in particular. This research combines the current attention to nutrient loading reduction by federal and state agencies with a local city's curiosity of how effective its stormwater structures are at providing better water quality.

The main objective of this research is to assess the effectiveness of select stormwater BMP's in Grand Forks, ND. This is to determine a baseline study, as well as develop a sampling plan that can be used in future continuation of the research.

The specific objectives include:

- Development of a long term BMP monitoring program – includes forecasting and frequency analysis of storm events, analysis of parameters tested for insignificance, modeling for appropriate time of concentration
- Cost-analysis of BMP structure based on effectiveness – provide recommendations to city officials

Storm event frequency analysis for precipitation events greater than 0.10 inches from 1994-2013 has been completed. In-situ BMP structures are being prioritized for sampling and water quality parameters to be tested have been decided. The sampling plan is currently being developed, as well as a Quality Assurance Project Plan (QAPP) that will outline all measures taken to ensure that the analysis is done accurately without bias. The logistics of items such as sample storage, access to laboratory equipment, and city of Grand Forks aid in sampling have been developed. Current progress puts sample collection beginning in May 2014 as planned.

Significance:

The U.S. Environmental Protection Agency (EPA) has begun efforts to expand regulations and strengthen the current program for individual states regarding stormwater. A new rule focusing on stormwater discharges from newly developed and redeveloped sites is expected to be finalized by December 2014 (Copeland, 2012). They also released a memo in March of 2011 that addressed how development of nutrient loading criteria is best handled at the state and local level (North Dakota Department of Health). In response to the EPA's request, the North Dakota Department of Health (NDDH) published the State of North Dakota Nutrient Criteria Development Plan in 2007 (Deutschman & Saunders-Pearce, 2007). The NDDH has recently put together a Nutrient Reduction Stakeholder group that has been working at creating the nutrient loading criteria to be applied throughout the state in year's to come.

Major sources of nutrients are municipality point sources and stormwater runoff in urban areas, among others. Pollution from nutrients, such as phosphorus and nitrogen, in waterways leads to eutrophication, which causes degradation of wildlife habitat and leads to concerns for public health. The city of Grand Forks aims to use the collected data from this research as a comparison to the nutrient criteria being developed at the state level.

Three Dimensional Analyses of Flow Dynamics & Chlorination of Ground Water Supply Reservoir in a Cold Region

Basic Information

Title:	Three Dimensional Analyses of Flow Dynamics & Chlorination of Ground Water Supply Reservoir in a Cold Region
Project Number:	2014ND283B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Engineering
Focus Category:	Methods, Treatment, Water Supply
Descriptors:	None
Principal Investigators:	Yeo Howe Lim

Publications

There are no publications.

Research

Storage tanks are designed to supply water demand as well as provide storage for fire-fighting. Generally, when operating under normal conditions a fraction of the water within the tank is utilized. Since chlorine decay occurs in relation with time, a combination of extended water age and unmixed tank conditions generates varying water quality throughout the tank. Previous literature documents water entering the storage tank with sufficient concentration and exiting with a chlorine concentration that is extremely low. When chlorine concentration is extremely low the possibility of bacterial growth increases impacting human health.

East Grand Forks, MN has experienced chlorine depletion in a particular storage tank in the past. To resolve the issue a tank mixer was installed to achieve completely mixed conditions. However, it is believed that if hydraulic conditions are taken into account during the design process, completely mixed conditions with higher water quality throughout may be efficiently achieved.

The main objective of this research is to create an accurate three-dimensional, multiphase, free surface, CFD model, utilizing ANYSYS CFX software.

Water temperature and chlorine concentration have been measured within the storage tank from January through April 2013. Soil temperatures were collected from North Dakota State Climate Office. CFD models have been created and initial conditions have been set. Currently, model computations are underway for the actual geometry of the tank in East Grand Forks as well as an alternative tank to geometry. Potential flow conditions for each geometry are considered and modeled separately. Based on completed outcomes, modeling three-dimensional, multi-phase, free-surface flow has been accomplished.

Significance:

Generally, water quality has been analyzed under the assumption that storage tanks are completely mixed. However, previous literature indicates otherwise based on field test. With the advancement of technology CFD software has begun to be implemented into the field of hydraulics. Previously, CFD analysis of storage tanks were modeled as steady state because of the extensive computation time and memory. This research considers unsteady flow conditions with fluctuating water levels as well as temperature interactions during the winter season.

Where is fertilizer nitrogen going, up in smoke or down the pipe? An assessment of nitrogen transformations and water quality impacts on a tile drained sodic soil

Basic Information

Title:	Where is fertilizer nitrogen going, up in smoke or down the pipe? An assessment of nitrogen transformations and water quality impacts on a tile drained sodic soil
Project Number:	2014ND284B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Irrigation, Nitrate Contamination, Agriculture
Descriptors:	None
Principal Investigators:	AnnMarie Fortuna

Publications

There are no publications.

Research

Tens of thousands of ha have been tiled annually, many of which are located on soils having a high risk for salinity or sodicity (i.e. Calciaquolls and Natraquolls). Yet, the effects of tile drainage on losses of reactive nitrogen (N) are largely unknown for these types of soil. Sodic soils, due to the structural limitations of excess sodium, have a high potential of being saturated. Tile drainage has the potential to improve nitrogen use efficiency, net primary productivity of row crops, and reduce gaseous losses of reactive N by eliminating saturated anoxic zones. However, tile drainage has been linked to greater nitrate leaching losses and reduced water quality. In sodic soils, leaching rates may be overestimated, while gaseous losses underestimated.

This work will measure nitrogen losses and plant uptake under tile drained and undrained conditions. Specifically, we will determine potential leaching rates of nitrate-N on a common sodic soil series.

The main objective of this study is to investigate the interactions between tile drainage, nitrogen uptake and losses on a sodic soil. Specific objectives include:

- Determination of plant nitrogen uptake from a sodic soil
- Assess whether tile drainage on a sodic soil increases nitrate leaching potential

Field plots with a tile drainage treatments (tile drained, controlled tile drained, and undrained control) were established in the fall of 2012 on an Exline soil (fine, smectitic, frigid Leptic Natrudolls) in Richland County, ND. Data on soil penetration resistance, soil enzyme activity levels for nutrient cycling, and soil chemical properties have been collected throughout the 2013 growing season.

Significance

Soil sodicity impacts over 4 million ha in North Dakota. Increases in salt affected areas are associated with elevated groundwater tables and precipitation patterns over the last 20 years. Agricultural producers in eastern North Dakota are installing subsurface tile drainage to aid in the removal of excess soil water with a secondary benefit of removing salts. Increases in tile drainage have been linked to water quality concerns as nitrates are easily leached through the tile drain. This work will assess nitrogen uptake in crops and nitrogen leaching potential in sodic soils.

Quantification of Spatio-temporal Distribution of Surface Ponding and Related Dynamic Processes

Basic Information

Title:	Quantification of Spatio-temporal Distribution of Surface Ponding and Related Dynamic Processes
Project Number:	2014ND285B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Models, Surface Water
Descriptors:	None
Principal Investigators:	Xuefeng Chu

Publications

1. Chu, X, and Habtezion, N, 2014. Applications of the Green-Ampt method across scales, p282-291. In: Water without Borders, Proceedings of the 2014 ASCE World Environmental and Water Resources Congress edited by Wayne C. Huber. American Society of Civil Engineers.
2. Noah Lebassi Habtezion, December 2014,Modeling of Surface Microtopography and Its Impacts on Hydrologic Processes, MS in Civil Engineering, North Dakota State University, Fargo, North Dakota.

Research

Surface depressions and the relevant surface ponding dynamics have unique hydrologic features and play important roles in overland flow generation, the occurrence of floods and droughts, the hydrodynamics and ecological functions of the associated wetlands, and the sustainability of the related agricultural systems in North Dakota. Thus, the knowledge of temporal and spatial distributions of depressions and the quantitative methods of surface ponding dynamics would improve the understanding of such problems and help identify effective strategies and solutions.

This study will focus on the important water resources topics with broad practical implications in North Dakota associated with surface ponding, depression filling-spilling-merging processes, and discontinuous overland flow. The specific objectives of this study are:

•to quantify surface depressions and surface ponding across temporal and spatial scales using the puddle-to-puddle (P2P) modeling system developed in our group, and

•to examine surface ponding dynamics and overland flow generation under the influence of a number of factors, including surface microtopography, rainfall features, soil properties, and initial soil moisture contents.

Significance

Specifically, the P2P model will provide detailed simulation outputs for all the scenarios, including puddles and their microtopographic characteristics, spatial and temporal variations in surface ponding, P2P filling-spilling-merging-splitting dynamics, outlet hydrographs, infiltration and unsaturated flow, soil moisture distributions, and hydrologic connectivity.

This study is expected to improve our understanding of the critical role of surface ponding and overland flow dynamics. Modeling of surface ponding has broad practical implications and application potentials across different fields. Particularly, such a detailed study on surface ponding and overland flow generation would potentially help identify better solutions for flood prediction and control.

Sodic soil characterization and management on subsurface drainage

Basic Information

Title:	Sodic soil characterization and management on subsurface drainage
Project Number:	2014ND286B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Water Quality, Irrigation, Agriculture
Descriptors:	None
Principal Investigators:	Tom DeSutter

Publications

1. He, Y., T. DeSutter, F. Casey, D. Clay, D. Franzen, D. Steele. 2015. Field capacity water as influenced by Na and EC: Implications for subsurface drainage. Geroderma 245-246:83-88.
2. He, Y., T.M. DeSutter, D. Hopkins, D. Wysocki, and D. E. Clay. 2014. The relationship between SAR1:5 and SARe of three extraction methods. Soil Sci. Soc. Am. J. doi:10.2136/sssaj2014.09.0384.
3. Yangbo He and Thomas DeSutter, December 2014,SODIC SOIL SWELLING AND DISPERSION AND THEIR IMPLICATIONS FOR WATER MOVEMENT AND MANAGEMENT Technical Report No: ND14-01, North Dakota Water Resources Research Institute,North Dakota state University, Fargo, North Dakota.
4. He, Yangbo, December 2014,Sodic soil swelling and dispersion and their implications for water movement and management, Ph.D in Soil Science,North Dakota State University, Fargo, North Dakota.

Research

Many soils in ND are being drained through the use of subsurface tiles. The purpose of subsurface drainage is to 1) decrease excess soil water, specifically at times of planting and harvesting and 2) remove soluble salts from the root zone (Chatterjee and DeSutter, 2012; Franzen, 2007). However, as noted by Cihacek et al. (2012), many of the soils may be negatively impacted because sodium is part of the exchange complex. Sodium is known a dispersant and this dispersion or swelling is accelerated when the concentration of soluble salts is reduced, which will likely occur in tile-drained soils (Cihacek et al., 2012; Curtin et al., 1994a). Dispersion and or soil swelling can lead to decreased Ksat, water percolation, and increased runoff, and finally a decrease in drainage performance. Currently there are no management strategies that have been developed for tile-drained soils in to help combat the effects of high sodium and low electrical conductivity or to prevent these phenomena from occurring. Detailed interpretation of chemical factors involved in sodic soils during tile drainage is incomplete.

The main objective of this study is the characterization and management of sodic soils for tile drainage. The specific objectives include:

•Determine physical and chemical properties (Ksat, dispersion, swelling, and pore volumes of water) of sodic soils

•Develop management guidelines and treatment options for sodic soils that will be or have been subsurface drained

Investigation of how pure clay minerals react under different sodicity and salinity levels was completed and paper with title of “Dispersion of pure clay minerals as influenced by Ca to Mg ratios, SAR, and EC” was published by Soil Science Society of America Journal (77:2014-2019). For the project for which I am seeking funding, the effect of solution electrical conductivity and sodicity levels on sodic soil water holding capacity has been completed. The manuscript is being prepared and plans to be submitted to the Journal of Soil and Water Conservation for review. The characterization of the spatial distribution of sodium as related to topography will be started in May 2014.

Significance

The disruptive effect of sodicity on the soil structural stability is a function of swelling and dispersion. Both of these processes may lead to a reduction of water infiltration and movement. Swelling commonly occurs in 2:1 dominant type of clays (like the clays we have in North Dakota) when water enters into their interlayer region. In sodic soils, high Na+ exists compared to divalent cations (Ca2+ and Mg2+). The size of Na+ has little disruption on the water within the clay’s interlayer close to clay surface and thus as the soil is wetted, water moves from the solution phase to these interlayers, causing swelling. When Na+ is present the interlayer water is “rigid” and does not easily flow. Swelling is maximized when the concentration of Na+, expressed as SAR (sodium adsorption ratio), is high and the EC is low, conditions that are typical of the Btn horizon in most sodic soils. This condition may also occur as salts are moved through the soil profile via gravimetric water in tile-drained systems. Therefore, improving our understanding of how subsurface drainage impacts soil chemical and physical properties is required for improved management of both sodium-affected soils and subsequent soil water.

Biopolymers for Phosphate Removal from Eutrophic Lakes

Basic Information

Title:	Biopolymers for Phosphate Removal from Eutrophic Lakes
Project Number:	2014ND287B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Nutrients, Surface Water, Water Quality
Descriptors:	None
Principal Investigators:	Achintya Nayan Bezbaruah

Publication

1. Mohammad Enayet Hossain, Talal Almeelbi, Harjyoti Kalita, Cody Ritt, and Achintya N. Bezbaruah. Phosphate Removal by Metal Cross-Linked Biopolymers. Proceedings of the ASCE/EWRI World Environmental and Water Resources Congress, Portland, Oregon, June, 2014. pp. 222-226 (5 pages)

Research:

Phosphorus (P) is important for the growth of plants and microorganisms in most ecosystems. However, excess phosphorus present in aquatic bodies leads to the overgrowth of algae and plant species (an indicator of eutrophication of the waterbodies). While eutrophication is a natural process, it is accelerated through anthropogenic activities. Accelerated eutrophication not only impacts the aquatic life but indirectly hampers the economic progress of communities that rely on aquatic food and other resources. Dissolved phosphate as low as ~0.02 mg/L is known to cause profuse algal growth in waters, thereby posing a host of problems. Eutrophication of lakes is a major problem in North Dakota. According to the North Dakota Department of Health (NDDH), ~52% (87 lakes) are eutrophic and ~17% (29 lakes) are hypereutrophic among the lakes surveyed. Further, ~56% of the lakes are considered threatened indicating that the continuation of current water quality and/or watershed trends would make it unlikely that these waterbodies will continue to support aquatic life and the water will be fit for human uses. The amount of P-compounds in waters should be reduced to prevent eutrophication of lakes and other surface waters. It is imperative to devise effective methods to remove excessive phosphate from water and wastewater. Presently, there is a significant gap in technology to remove low concentration P from waters, specifically from eutrophic lakes. There is another aspect to the P issue. Phosphorus for fertilizer production is mined chiefly from select phosphate mines from Morocco, Western Saharan region, Peru, and China. The United States' phosphate imports come from Morocco and Peru. Phosphorus is a nonrenewable resource and a recent assessment indicated that natural phosphate deposits will last for approximately 60-240 years. The present NDWRRI research involves the use of novel biopolymer beads for phosphate removal and reusing the beads (with sorbed phosphate) for agricultural purposes as source of phosphate for plants. The research, if successful, will provide a robust and sustainable technology (or technologies) to remove and recover aqueous phosphate.

The main objective of this research is to determine if biopolymer beads can be used to remove aqueous phosphate and then use the phosphate as a plant fertilizer. The specific objectives of this work are:

1. To investigate the phosphate sorption characteristics of the beads

2. To identify the sorption and desorption mechanisms

3. To determine the feasibility of using the beads in eutrophic lakes

4. To measure the bioavailability of bead removed P for agriculture uses

Significance:

This research work will enable us to alleviate the problem of eutrophication of lakes. In addition to dealing with eutrophication, this research will contribute towards generating a new source for phosphorus for agricultural uses and, thus, contribute towards better crop production in North Dakota and improve global food security.

A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota

Basic Information

Title:	A Study of the Spatial and Temporal Characteristics of Drought and its Impact in North Dakota
Project Number:	2014ND288B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Hydrology, Climatological Processes
Descriptors:	None
Principal Investigators:	G. Padmanabhan

Publications

1. Odabas. M., Leelaruban. N., Halis Simsek, and G. Padmanabhan (2014) Quantifying Impact of Droughts on Barley Yield in North Dakota, USA Using Multiple Linear Regression and Artificial Neural Network. Neural Network World, Vol. 24, No.4, pp. 343-356.
2. Halis Simsek, Bilal Cemek, Leelaruban, N, G. Padmanabhan., An assessment of drought impact on barley yield using a county wide drought Severity and Coverage Index and Adaptive Network-based Fuzzy Inference System (ANFIS) Model. Proceedings of the 2nd International Symposium on Innovative Technologies in Engineering and Science (ISITES), 18-20 Jun 2014, Karabuk, Turkey.

Research:

Drought is a complex phenomenon, and difficult to accurately describe because of its complex characteristics. It is well known that drought is a spatially and temporally varying natural hazard. Understanding drought severity, frequency, duration, and spatial extent is critical in drought mitigation and planning. It is crucial to understand how drought propagates in space and time for effective management and mitigating measures. Also, it is well known that drought significantly impacts agriculture, environment, and society. A clear understanding of drought impact on these sectors will help address planning for future droughts. Quantifying drought impact is difficult because of the complex characteristics of drought and also the impacted sectors.

Various drought indices are used to identify and monitor drought situations, and to decide the timing and level of drought responses. The most commonly used indices include (i) Palmer Drought Severity Index (PDSI) (ii) Standardized Precipitation Index (SPI) (iii) Crop Moisture Index (CMI) and (iv) U.S Drought Monitor Index. All except the last one are severity indicators and do not reflect the spatial extent of droughts. Each index has its own advantages and disadvantages from the users' perspectives. A composite index which will reflect the severity and spatial coverage corresponding to that severity together, particularly at the county level will be useful for resource allocation for drought mitigation purposes.

It is estimated that drought costs the United States $6–8 billion annually. Drought creates stress on water sources (i.e., surface water, groundwater), and on soil moisture. This will impact water-dependent industries including agriculture, water supply, and recreation. Researchers have developed several techniques to understand the drought impact.

There is still a need for comprehensive drought study to understand the drought and its impact in North Dakota. Especially, the recent development and availability of computational tools can help develop better understanding of drought. The recent drought events in this region emphasize the need for a rigorous drought study.

Objectives of the study are:

1. To study the drought propagation mechanism based on the geospatial and temporal characteristics of droughts to gain a better understanding of the phenomenon

2. To study the impact of drought on water resources and agriculture in North Dakota

A refined county-level drought Severity and Coverage index is developed for drought management based on U.S Drought Monitor (USDM) drought severity and coverage values. The spatial variation of drought severity and frequency within North Dakota are analyzed and mapped. Based on the relationship between crop yield and USDM severity coverage values a crop specific county-wide drought Index is proposed. Transition probabilities are derived for crop yield categories from state of less severe drought year to more severe drought year using Markovian process. Impact of drought on barley yield is studied using Multiple Linear Regression and Artificial Neural Network. Responses of groundwater level to drought are being investigated based on drought severity and duration.

Significance:

North Dakota has experienced several drought events in the past. The impact of drought in this region has significant influence on the economy, social, and environmental sector of North Dakota. This study will analyze the characteristics and impact of drought in this region. The results of this study will be useful for state agencies, and water dependent industries to plan and manage the future drought events. In addition, this study will propose potential actions to be taken in order to improve the drought monitoring and mitigation in the state of North Dakota. Though this study focuses on the state of North Dakota, the methodologies used in this study can be adopted for other places. In general, this research will contribute to understand the propagation mechanism of drought, and assess the impact of drought on agriculture and groundwater resources using novel approaches.

Snowmelt water infiltration into frozen soil in Red River of the North Basin

Basic Information

Title:	Snowmelt water infiltration into frozen soil in Red River of the North Basin
Project Number:	2014ND289B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Models, Groundwater
Descriptors:	None
Principal Investigators:	Xinhua Jia

Publications

There are no publications.

Research:

Snowmelt water infiltration into frozen soil is an important but complicated process that can affect surface water runoff and groundwater recharge. Many factors, such as soil moisture, soil temperature, water release rate from the snow cover, energy content of infiltrating water, porosity, soil cracks, presence or absence of macropores and also complex processes of heat and mass transfer through the frozen soils affect the total infiltration process into frozen soils. In northern hemisphere, nearly 60 percent of the land surfaces are seasonally frozen and North Dakota is a part of that area. There is no simple and clear answer on how water infiltrates into frozen soil. The lack of understanding of the infiltration process into frozen soil is the major limiting factor affecting spring flood forecasting. In recent years, during the spring flood events in the Red River of the North Basin (RRB), flood forecasting cannot be estimated accurately due to lack of data on infiltration into frozen soil. Any error in flood prediction can cause significant financial losses and threaten 200,000 people lives in the Fargo-Moorhead metro area as well as people and animals in the entire basin. The proposed research project will focus on snowmelt infiltration characteristics into frozen soils. A snowmelt water infiltration model will be developed which can help to overcome the current obstacles in order to accurately predict spring flood.

The research project will focus on snowmelt infiltration characteristics into frozen soil. The specific objectives of the research study are:

- To measure infiltration amount/rate into frozen soil at field and laboratory conditions.
- To develop a snowmelt water infiltration model based on historic, laboratory and field data.
- To evaluate model outputs with other available infiltration models.

Hydra Probe II sensors for soil moisture and temperature measurement, SR50A Sonic ranging sensor for monitoring snow depth, and modified TE525 rain gage for rainfall and snow fall measurement are installed in the field. Three wireless weather stations were also set up in the research site to collect weather parameters like air temperature, relative humidity, solar radiation, wind speed and direction. A Cornell sprinkler infiltrometer is now being calibrated and tested in field for infiltration measurement.

Significance:

Understanding the infiltration process into frozen soils could have a broad impact to the hydrological field for the entire and especially in permafrost regions. It would help to better understand the runoff processes and flooding events in winter and spring. Properly adjusted numerical infiltration model could be used to predict actual runoff peaks to prevent damage from floods or to prevent overestimation of runoff. The benefit from this proposed study will be several million dollars each year in flood preparation.

Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species

Basic Information

Title:	Evaluation of Bioavailable Dissolved Organic Nitrogen Using Various Algal Species
Project Number:	2014ND290B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Treatment, Surface Water, Water Quality
Descriptors:	None
Principal Investigators:	Halis Simsek

Publications

There are no publications.

Research

Dissolved organic nitrogen (DON) from final effluent of WWTPs and animal feedlots from agricultural areas are important nutrient sources for bacterial and algal communities in surface waters such as rivers, lakes, and estuaries. Excess amount of DON in surface waters can cause excess algal growth and dissolved oxygen depletion and ultimately cause eutrophication in water ecosystem. Bioavailable DON (ABDON) is a fraction of DON that is directly or indirectly available as a nitrogen source for algal species through hydrolysis process. ABDON is calculated as the differences of DON initial and DON final during the incubation period. This research will provide the data that both plants may expand their effluent qualities by reducing DON and TDN and may reduce the treatment cost by using algae in the WWTPs. Algal usage in WWTPs will provide a basis for protecting aquatic ecosystems from cultural eutrophication.

The main scope of this study is to collect DON and ABDON data from three locations of two different WWTPs and two locations from animal feedlots in order to achieve the following objective:

1. To investigate DON and ABDON for four different algae species in a two-stage trickling filter and an activated sludge WWTPs, and in an animal feedlots.

2. To examine mixed culture algae and algae + bacteria interactions for 4 different algal species to determine the best algal species to utilize ABDON.

Two sets of experiments determining ABDON using algae Chlamydomonas reinhardtii, and Chlorella vulgaris has been completed with different stages of wastewater from Fargo WWTP. Algae will be used in animal wastewater samples from feedlot to evaluate the ABDON under high nutrient conditions.

Significance

This research will provide important outcomes to improve the quality of surface waters (rivers, lakes. etc.) in North Dakota by minimizing the nutrient entrance to water ecosystem either from WWTPs or from animal feedlots. Using algae to treat the wastewater is a natural and cost effective way. For the first time, different algal species will be used to examine the bioavailability of dissolved organic nitrogen in a two-stage trickling filter WWTP. Determining the best treatment condition for per pure-cultured and/or mixed cultured algae will help us to understand nutrient removal potential of algae very well.

The Role of Algal Species on Phosphorus Bioavailability

Basic Information

Title:	The Role of Algal Species on Phosphorus Bioavailability
Project Number:	2014ND291B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Treatment
Descriptors:	None
Principal Investigators:	Khan Eakalak

Publications

There are no publications.

Research

Eutrophication of waters is one of the major issues society faces, it degrades water quality and can lead to dead zones such as in the Gulf of Mexico. Phosphorus is one of the key nutrients that lead to eutrophication when sufficient concentrations are present in water bodies. However it is the bioavailable phosphorus (BAP) that is of real concern, because this is the phosphorus algae use to grow. S. capricornutum has been the standard algal species utilized to estimate BAP. This study will utilize two additional species, C. vulgaris and C. reinhardtii, for the comparison of BAP estimates.

It is hypothesized that BAP differs between different algal species as organisms fill different niches in ecosystems. There is little research concerning BAP especially in the area of environmental engineering. This research will further our understanding of phosphorus and how it is utilized by algae after being discharged and can impact how future nutrient standards are managed.

The main objective of this study is to investigate phosphorus bioavailability when examined from multiple algal species. The following objectives have been developed:

- Determine BAP from three different species when present individually and as a group.
- Analyze P-species distribution before and after bioavailability assays.
- Investigate the effect of enzymatic activity on BAP
- Evaluate the effect of pretreatment of samples with UV radiation on BAP.

Methods to measure the different phosphorus fractions have been determined and standards curves replicated successfully. Various methods of measuring algal growth for the determination of BAP have been explored and a method selected. Standard curves comparing algal growth to BAP will be created shortly. Samples incubated with the mixed algal inoculum will be examined through a microscope at the end of the incubation period in order to determine algal species ratios and to determine which algal species compete for nutrients more efficiently. After the replication of standard curves for algal growth and therefore BAP, secondary effluent samples will begin to be examined.

Significance:

Results will show whether BAP estimates vary between different algal species. If results vary this research will show that the current standard algal species of S. capricornutum is not necessarily a reliable estimate of BAP and that other algal species may provide a higher estimate of BAP. The research will also show how the algal species affect the concentration of the different P-species from multiple WWTP effluents.

The effects of enzymes and UV light on P-species and their potential to convert non-BAP to BAP will also be determined. This provides further understanding on how algae and other physical factors are converting the P-species into usable forms that can be taken up by algae.

Information Transfer Program Introduction

Information dissemination is done through an annual newsletter, and presentations and publications by grant and fellowship recipients. A web site also helps disseminating institute research information. The institute's website address is http://www.ndsu.edu/wrri. Past newsletters can be accessed through the institute web site. Technical reports of Fellowship projects authored by the Fellows and advisers are also placed on the institute web site.

Information Dissemination and Communication

Basic Information

Title:	Information Dissemination and Communication
Project Number:	2014ND292B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	001
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	G. Padmanabhan

Publications

There are no publications.

Activities to disseminate institute and other research under this project included:

1. Maintaining web site as an effective way communicating to the public
2. Publishing the annual institute newsletter
3. Publishing Fellowship and other research done through the Institute
4. Hosting the annual "Distinguished Water Seminar"
4. Presenting research results to state and federal water agencies
5. Sponsoring or co-sponsoring local or regional conferences

The website of the Institute was updated at least quarterly, and more often when a research project wished to provide updates or when a Fellow graduates. The website provides additional details on the research. The list of Institute Affiliate Faculty with their expertise was updated. Research reports published by the institute were placed on this web site as and when they became available. The institute web site is: http://www.ndsu.edu/wrri .

The Institute continued its annual newsletter, which highlighted the graduate research fellowship program, the research grants associated with it, and general summaries of ongoing research. The newsletter profiled institute research and researchers and published other newsworthy water issues in the State.

The Institute continued its off-campus seminar series, designed to enhance communication between the State and Federal agency personnel and university faculty and students. Advisors and fellows present their research results to State and Federal professionals in Bismarck, the state capital. The Institute also encouraged its Fellows and faculty to attend seminars and conferences held in the region. Modest support to Fellows for travel was provided by the institute.

Several North Dakota Water Resources Research Institute fellows and affiliated faculty from NDSU and the University of North Dakota presented at the 2014 North Dakota Water Quality Monitoring Conference March 4-6 in Bismarck, N.D.

The institute partnered with North Dakota Department of Health, N.D. State Water Commission, N.D. Game and Fish Department, U.S. Geological Survey and U.S. Department of Agriculture to host the event, which was attended by more than 100 water professionals from North Dakota and surrounding states.

G. Padmanabhan, professor of civil and environmental engineering and director of the institute, served on the conference planning committee.

Francis Casey, professorand director of the NDSU School of Natural Resource Sciences was one of the keynote speakers. His talk was titled "Estrogenic Hormones in the Environment." Casey is an affiliate faculty of the Institute.

Several past and present North Dakota Water Resources Research Institute graduate fellows, NDSU students and their advisers presented at the conference. Podium presentations included:

•"Under the radar: Nanoparticles and rare earth elements as emerging pollutants" Marinus Otte, NDSU professor of biological sciences, and Donna Jacob, NDSU research assistant professor of biological sciences

•“What, When, and Where in Studying the Best Management Practices (BMPs) in Grand Forks, N.D.” Yeo Howe Lim, UND associate professor of civil engineering
•“Prioritizing aquifer monitoring in North Dakota: Geochemistry is important too” Scott F. Korom, UND associate professor of geology and geological engineering, and William Schuh, North Dakota State Water Commission
•“Plant Phosphorus, Nitrogen, and Carbon and Soil Phosphorus in North Dakota Wetlands” NDSU student Lindsey Meyers
•“The National Wetland Condition Assessment in North Dakota: Preliminary Results” Shawn DeKeyser, NDSU associate professor of range science
•“Three Discovery Farms…Three Unique Water Quality Stories” Rochelle Nustad, institute fellow
•“Remediation of Nutrients from Feedlot Runoff by Plants” Arjun Thapa, NDSU student
•"Monitoring tile drainage and subirrigation water quality using electrical conductivity” Xinhua Jia, NDSU associate professor of agricultural and biosystems engineering
•“Nitrate-Nitrogen in Soil Water as Affected by Nitrogen Management in Sugarbeet under Subsurface Drainage Condition” NDSU student Rakesh Awale
•“Monitoring water quality in Devils Lake in real time” Xiaodong Zhang, UND associate professor of earth systems science and policy
•“Waste Load Allocation Modeling of an Intermittent Stream” Jayme Klecker, NDSU BS ’98, civil engineering

Poster presentations included:
•“Multi-Elements in Pothole Wetlands – investigating the trace and rare earth elements” Donna Jacob, NDSU research assistant professor of biological sciences
•“Ecotoxicity of Single-Walled Carbon Nanotubes and Zinc Oxide Nanoparticles Suspended in Water” NDSU student Amanda Grosz
•“Iron Cross-linked Biopolymers for Phosphate Removal” NDSU student Mohammad Hossain
•“Uncertainty analysis of load estimation for the nutrient TMDLs for Lake Ashtabula” NDSU student Mengqi Xiong, Zhulu Lin, and G. Padmanabhan
•“Mapping the Fate of Nutrients at the Abandoned Crookston Cattle Company Feedlot” Phil Gerla, UND associate professor of geology and UND student Prosper Gbolo
•“Nanoparticles in Water and Interaction in Plants” NDSU student Priyanka Deka
•“Nanoparticles for Remediation and Disinfection of Water” NDSU student Achintyamugdha Sharma
•“Coating Nanoscale Zero Valent Iron with Modified Food Starch for Improved Colloidal Stability” NDSU student Mary Pate

The annual 4th Distinguished Water Seminar sponsored by the Institute was held on February 19, 2015. The featured speaker was Dr. Gregory V. Lowry, Water J. Blenko Sr. professor of civil and environmental engineering at Carnegie Mellon University in Pittsburgh. Dr. Lowry, is also the deputy director of the Center for Environmental Implications of Nanotechnology of CMU. The topic title was "Nanotechnology in Water Science and Engineering: Sustainably Harnessing the Power of Nanotechnology."

Dr. Lowry presented an overview of the history of the Environmental Nanotechnology field, and recent advances in applications and implications of engineered nanomaterials in water science.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	5	0	0	0	5
Ph.D.	5	0	0	0	5
Post-Doc.	0	0	0	0	0
Total	10	0	0	0	10

Notable Awards and Achievements

Publications from Prior Years

1. 2013ND273B ("Electron Donor Contributions to Denitrification in the Elk Valley Aquifer, ND") - Dissertations - Amanda Kreiger, May 2014, Electron Donor Contributions to Denitrification in the Elk Valley Aquifer, North Dakota, M.S. in Geology and Geological Engineering, University of North Dakota, Grand Forks, North Dakota.
2. 2013ND274B ("Physical model evaluations of scour holes below a singular and multiple step rock weirs") - Dissertations - Brian Mager,May 2014, Physical Model Studies of Scour Holes below Singular and Multiple Step Rock Weirs, M.S. in Civil Engineering, University of North Dakota, Grand Forks, North Dakota.
3. 2013ND277B ("Drought monitoring and prediction using NOAH land surface model and GRACE satellite observation") - Dissertations - Wu,Jiexia., May 2014, Agricultural drought monitoring and prediction using soil moisture deficit index, M. S. in Earth System Science & Policy, Dept. of Earth System Science and Policy, University of North Dakota, Grand Forks, North Dakota.
4. 2012ND257B ("Toward Understanding the Hydrologic Processes on Topographic Surfaces with Depressions - Development of a Physical-based Distributed Puddle-to-Puddle (P2P) Hydrologic Model") - Dissertations - Yang, Jun., May 2014, Microtopography-dominated Discontinuous Overland Flow Modeling and Hydrologic Connectivity Analysis, Ph. D in Civil Engineering, North Dakota State University, Fargo, North Dakota.
5. 2012ND260B ("Role of Agricultural Drainage on Transport of Cryptosporidium oocysts in North Dakota") - Dissertations - Wadhawan, Tanush., December, 2014, Investigating Biodegradability of Dissolved Organic Nitrogen in Oligotrophic and Eutrophic Systems, Ph.D in Civil Engineering, Civil and Environmental Engineering Dept., North Dakota State University, Fargo, North Dakota.
6. 2013ND274B ("Physical model evaluations of scour holes below a singular and multiple step rock weirs") - Conference Proceedings - Lim, Y.H. and Mager, B. (2015). Model Studies of Singular and Multiple Step Rock Weirs: the Influence of Design Parameters on Scour Depths. Proc., World Environmental and Water Resources Congress 2015- Floods, Droughts, and Ecosystem, p 1760-1768, Environmental and Water Resources Institute, ASCE, Austin, Texas.
7. 2009ND188B ("Ion Imprinted Polymer for Removal and Monitoring of Arsenic (Phase II)") - Articles in Refereed Scientific Journals - Bezbaruah, A.N., Kalita, H., Almeelbi, T., Capecchi, C.L., Jacob, J.L., Agrinov, A.G., and Payne, S.A., 2014. Ca-Alginate Entrapped Nanoscale Iron: Arsenic Treatability and Mechanism Studies, Journal of Nanoparticle Research, 16:2175, 2014.